SEISMIC MOTIONS OF VERY SOFT GROUND

by

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SYNOPSIS

One of the characteristics of ground shaking which has a remarkable effect on the structures on a very soft ground will be large values of the maximum and the relative displacements. The anti-earthquake safety counterplan for trains running at high speed at which we set our final aim is no doubt to prevent trains from derailment or overturn during earthquake. When a train passes a bridge built over a soft ground and the deformation of track caused by earthquake exceeds a certain limit, the train is likely to be derailed, even though the structure of the bridge itself may not be damaged. Such a deformation is frequently to be caused by the ground and the structure responses to earthquake. We are now carrying out an observation of such seismic motions as contain the wave components of some long period by array method in the soft ground. The result of the observation has made clear the nature of such ground shaking as causes a relative displacement which we call "snake motion". We found that the difference of phase and amplitude between waves at the points adjacent to each other is affected by the kind of waves, the path of waves, the inclination of boundary between the surface soft layers and the hard underlayer base and so on.

INTRODUCTION

As anti-earthquake safety measures for trains running at high speed of 260 KM/H on a bridge built on a very soft ground, the follwing four points were investigated.

1) To analyze the nature of such a kind of wave irregularity as we call "snake motion", at the spots adjacent to each other on the ground.

2) To develop a new foundation structure type of bridge which is able to endure great ground displacement.

3) To modify the conventional train stopping system so that running trains may be stopped as quickly as possible during earthquake, to be applied for a special case of designing a bridge where no safety measures are available.

4) To develop such a new track structure that trains, even when derailed, may not be overturned.

In this thesis, mainly the points NO.I and partially NO.2 are explained and NO.3 is to be done in a separate thesis.

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PURPOSE OF EARTHQUAKE OBSERVATIONS BY ARRAY METHOD

For the point NO.1 mentioned above, it is essential to know the maximum ground displacement and the wave difference of phase and amplitude at the points adjacent to each other on a very soft ground during earthquake. Unfortunately, however, practically nobody has studied the nature of such ground shaking from this standpoint except Sakurai (1969) and others, and, therefore, we have carried out such observations by array method on the following two kinds of soft grounds.

The first one is an extremely soft ground in alluvial flood plain where big damage to railway embankments and bridges was actually caused by Tokachioki Earthquake in 1968. In this case, we intended especially to analyze how the wave shapes at the points adjacent to each other on the ground surface were affected by the kind of waves, the path of waves, and the inclination of boundary between the surface soft layers and the hard underlayer base.

The second one is a narrow drowned valley where a new type of bridge mentioned in the above point NO.1 is to be built. In this case, we intended to analyze the displacement distribution, particularly of the vertical motions, of ground shaking on a soft ground in a round valley.

INSTRUMENTS AND GEOLOGICAL FORMATIONS ON THE OBSERVATIONS

In the first kind of soft ground of alluvial flood plain, the observation network and some contour lines of the thickness of soft layers are shown as Fig. 1. Two kinds of seismographs, the displacement type of overall frequency range 10 to 0.1 Hz and the acceleration type of the range 20 to 0.5 Hz, have been installed on or beneath the ground in this network. The vibrational components of them are one to three at every point. The seismic output from them is telemetered over wire, amplified and recorded by data recorders through delay circuits of ten seconds.

A schematic view of geological formations of the site is given in Fig.2. The velocities of S wave at every layer, or the mean velocities of S waves at some layers, are indicated in this figure. A velocity of less than 50 m/sec is that of extremely soft layers, alluvial peat or clay layer. The boundary between the alluvial soft layers and the diluvial hard underlayer base is parallel to the surface at the central part and inclined upward at the end part in the plain as is shown in the figure.

For the second kind of ground of narrow drowned valley, the distribution of observing points and an outline of geological formation are shown in Fig. 3. It is to be regretted that the observation here is now suspended because of a certain trouble with the Agricultural Land Law, because a soft ground generally belongs to a rice-productng district.

DATA ANALYSIS

Some seismic data have been obtained through observation at the first site mentioned above. Figure 4 shows the typical observed waveforms for the two points of NO.1 and NO.8 in Fig.2 and the following results. In the Fourier spectra from these data we can see that almost no frequency component more than

5 Hz appears in the records of displacement type. The frequencies which we expect to analyze for this purpose are also in the range of about 0.5 to 5 seconds depending on the structure of which the proper period is the longest in the railway bridges except suspension bridges. Considering such a range, we found that the frequencies of the peak amplitude are 0.5, 2.1 and 2.6 Hz and the phase differences of the two waves at each frequency are 0.36, 0.22 and 0.05 seconds respectively, as the result of the frequency response analysis of the filtered data from the two waves shown in Fig. 4. These two points separated by 700 meters are on such different grounds as alluvial deposits and diluvium. From these facts we can hasten such a study that the analytical results of the similar data from the points NO.1 to NO.6 on the same soft ground would show a stronger mutual correlation of the waves obtained at every point after the accumulation of data.

NEW FOUNDATION STRUCTURE TYPE OF BRIDGE OVER THE DROWNED VALLEY

To avoid such an accident during earthquake as derailment or overturning of a train passing a bridge built over a soft ground, the following new reinforced concrete continuous girder bridge has been developed for the point NO.2 mentioned in the early stage of this paper. In this bridge, rigid abutments are set up on the outcrops at both banks of the valley and they bear the total horizontal load caused by earthquake, whereas piers which are set up on a soft ground in the valley can bear only the vertical load of the girders. Thus, girders and piers are so designed as to slide freely in the horizontal direction. An outline of this bridge is illustrated in Fig. 5.

CONCLUDING REMARKS

The following conclusion was drawn from our observation and analysis.

(A) Generally speaking, the phase difference between waves is small when periods of wave are long but becomes larger as periods become shorter, although it differs according to the kind of waves, the path of waves and the subsoil structure.

(B) For the period of less than one second, the waveforms recorded are considerably different between soft ground and hard ground. In hard ground, a short period component is predominant.

(C) For waves with the component of comparatively long period, waveforms which have been filtered appropriately show a strong correlation even between soft ground and hard ground. From this fact the waves of some long period components during earthquake are likely to be contained commonly at every point their length being less than about one kilometer, and a comparison of the phase difference of waves would lead to still useful results coupled with theoretical studies after the analysis of more data.

ACKNOWLEDGMENT

The present research has been conducted as a part of activities of the Committee on Anti- earthquake Measures for SHINKANSEN. The author's gratitude is here extended to the members of the Committee for their kind suggestion or cooperation. It should be noted that Miss E. Ohfusa has been mainly responsible for the data processing through the FACOM 230-35 computer of our institute.

REFERENCE

Sakurai A. and T. Takahashi, 1969, Dynamic Stresses of Underground Pipe Lines during Earthquakes, Proc. 4th W.C.E.E.

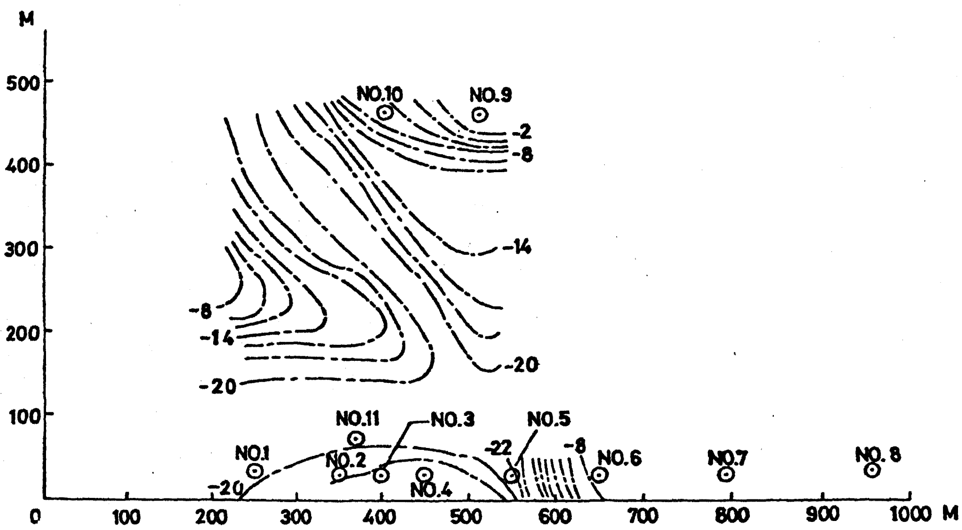

Fig. 1 The observation network and the contour lines of the thickness of soft layers on the first site.

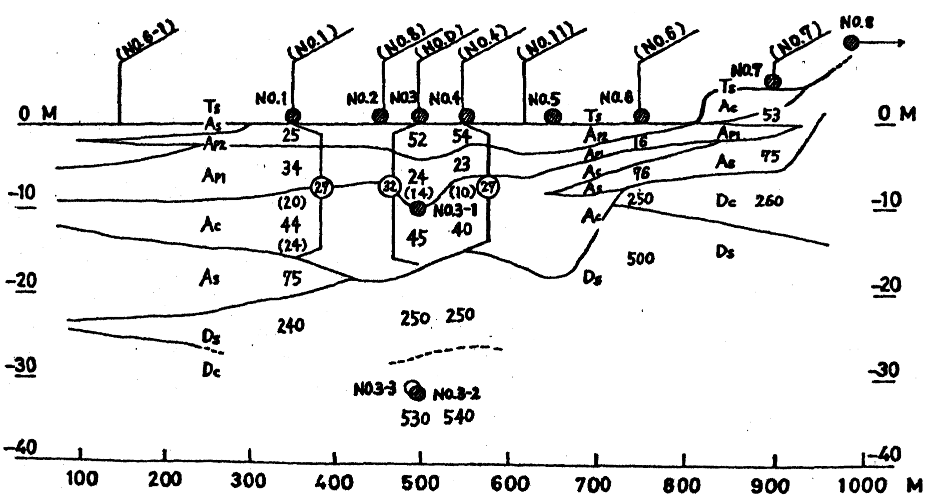

Fig. 2 The schematic view of geological formations of the above site. Numbers in the underground show S-wave velocities.

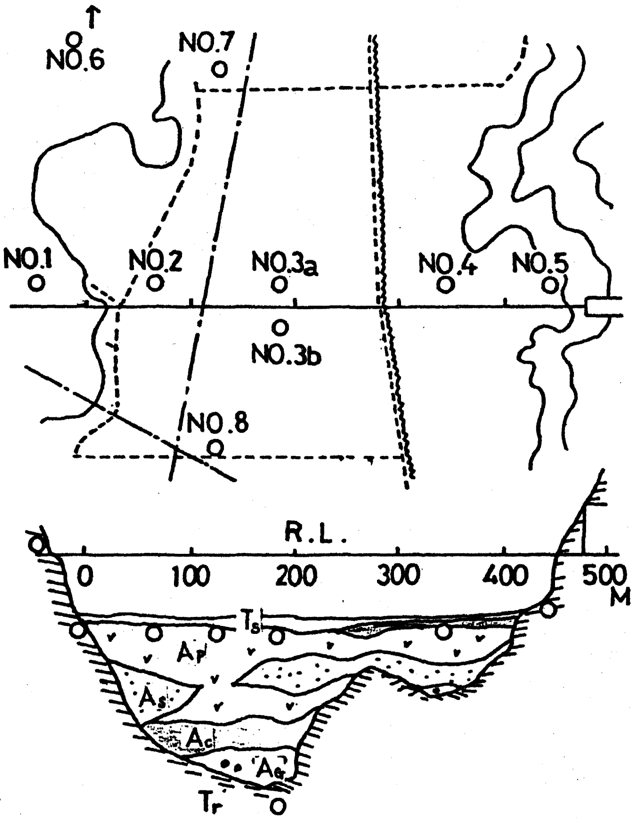

Fig. 3 The observation spots and the outline of the geological formation on the second site.

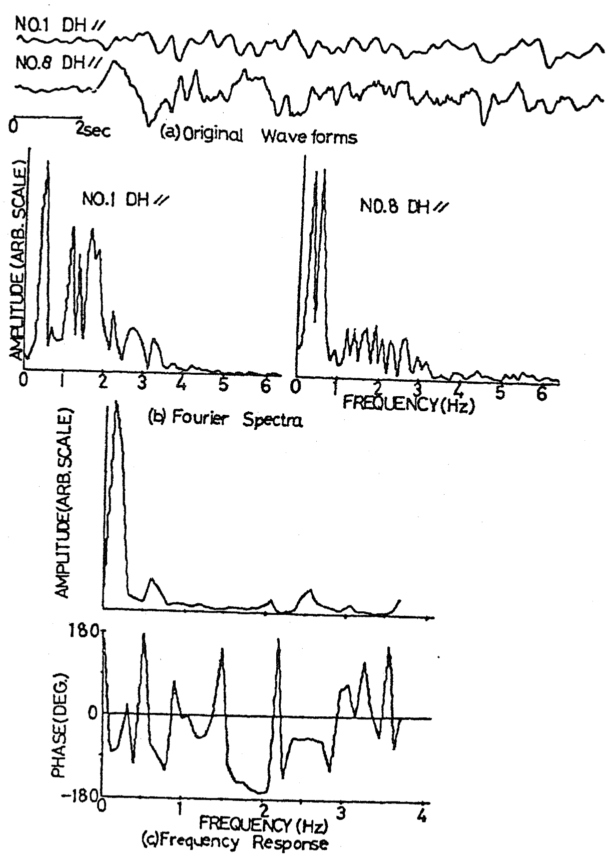

Fig. 4 (a) shows the observed waveforms of horizontal component at the points NO.1 and NO.8 on the first site. (b) is the Fourier spectra and (c) shows the Frequency response curve, from (a).

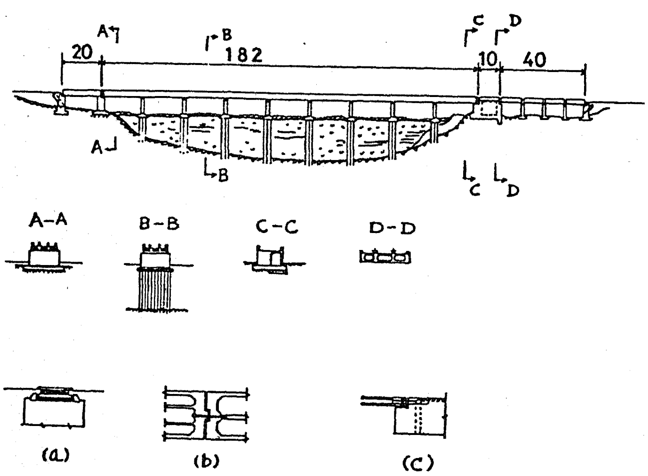

Fig. 5 The outline of the new type of bridge on the second site. (a) is the sliding-free bearing, (b) is the horizontal section of the bearing and (c) is the longitudinal section of the bearing.

DISCUSSION

R. Guzman (U.S.A.)

Would you please describe the characteristics of the soils ?

Author's Closure

Regarding the querry by Mr. Guzman, author's closing remark is that the characteristics of the soils are given in Fig. 2. In this figure, Ts, Ap2, Apl, Ac, As, Dc and Ds denote top soil, fibrous peak, alluvial peak, alluvial clay, alluvial sand, diluvial clay and diluvial sand respectively. Numbers such as 25, 34 and so on are S-wave velocities in m/sec, and 27, 32 etc are the mean velocities in the layers. The density of peak layer is about 1.2 gr/cm^3.